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Progress Report and Future Plans

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Carbonate Platform Development &Stromatolite Morphogenesis: Constraints on Environmental and Biological Evolution

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NASA Exobiology Grant

J. Grotzinger, MIT, May 10, 2002

Work this past year has focused on the globally significant events of faunal turnover, tectonic reorganization, and biogeochemical change that closely coincided with the Precambrian-Cambrian boundary in the Sultanate of Oman. Higher temporal and chronostratigraphic resolution are required in order to answer this question. Stratigraphic sections must contain fossils, volcanic rocks, and abundant carbonates with little or no diagenetic overprint. The Ara Group of the South Oman Salt Basin presents such a succession — with carbonate rocks tightly enclosed in a protective envelope of impermeable halite, these rocks have likely never exchanged with younger fluids.

Our work has had two thrusts. The first pertains to the geochemistry of the Athel Formation, a deep water deposit formed at the Precambrian-Cambrian boundary which contains unique records of ocean anoxia for that time interval. This unit is important because it will enable tighter focus on the links which existed between global biogeochemical events and episodes of faunal extinction and radiation. The second direction involves a comparison of terminal Proterozoic thrombolites between Oman (subsurface) and Namibia (outcrop). These thrombolites are important not only as significant deposits of ancient microbial communities, but because they formed the key substrate for growth of the oldest calcified metazoans — *Cloudina* and *Namacalathus*.

Future Work

Our current NASA Exobiology effort proposes to undertake work in Alaska. We have decided not to undertake this work at this time, because the work in Oman is producing unexpectedly spectacular results. It is safe to say that this may be the best place in the world to decipher key events related to the Precambrian-Cambrian boundary. The combination of having the fossiliferous carbonate rocks enclosed in salt (which prevents their exchange with damaging diagenetic fluids), and their exposure for the past 550 million years to basin temperatures never exceeding 90° C in most cases (which prevents thermal degradation of organic matter) has produced an unprecedented storehouse of biogeochemical proxy records. Our goal is simply to try and get all we can out of this basin before moving on to the next field site.

Athel Geochemistry

Current Results. Work during the first phase of the project focused on: (1) interpretation of available trace element data; (2) development of an analytical method for further analysis of trace elements; and (3) initial Re-Os dating of the Athel Fm. Petroleum Development Oman provided trace element concentrations for some wells in the study area. Samples are generally enriched in most redox-sensitive elements, notably authigenic U and V. Element ratios are compatible with partially dysoxic–anoxic conditions in the sediments, and the redox state probably underwent strong fluctuations. Analytical work at MIT has concentrated on the development of digestion and measurement procedures to expand this dataset to other wells. In addition, analytical work has also shown the potential of the Re-Os method for dating of the Athel Fm. black shales. Analysis of the first twelve samples yielded a Re-Os age of *c.* 540 Ma, although the error of this age is still considerably high, due to significant data scatter.

Future Work. Future work on Athel Fm. redox geochemistry will extend the first results to other wells in the study area and will apply other geochemical proxies. Digestion and measurement procedures are being developed for the ICP-MS at MIT. This will allow analysis of more samples in-house, and the suite of redox-sensitive elements can include additional elements, e.g. REE. In addition, samples will be sent out for analysis of $\delta^{13}C_{org}$. Coeval platform carbonates show a negative excursion of $\delta^{13}C_{carb}$. Comparison of this shallow-water signal with the deep-water signal provided by black shale $\delta^{13}C_{org}$ will constrain the isotopic evolution of waters during deposition of the Athel Fm. Re-Os work will focus on refining the data obtained in the first project phase. If suitable, additional samples may be analyzed to expand the database. Anhydrite rocks associated with the platform carbonates could provide an independent Re-Os age, because the elements Re and Os may substitute for the sulfur phase of the anhydrite.

Thrombolite Facies

Current Results. Exposures in Namibia allowed the logging of sections through thrombolite reefs and the mapping of the spatial and temporal reef distribution. Reefs developed on a high-energy carbonate ramp. Reef mounds are elongated parallel to the paleo-fetch direction of waves and storms. Massive thrombolites, growing under conditions of reduced sedimentation rate, alternate with stromatolites that correspond to higher sediment fluxes. Results suggest that most favorable conditions for thrombolite reef growth occurred during times of increased accommodation and lowered sediment flux. Reef growth clearly responded to environmental factors such as storms and sediment flux. On the other hand, the mesoscopic microbial reef framework remained relatively simple. By comparison, in Oman, only 1-dimensional cores are available for study. However, observations are similar to Namibia, for example the same types of mesoscopic microbial reef framework, and the internal zonation of reefs. Therefore, inferences on the spatial and temporal distribution of thrombolite reefs seem to be applicable to both study areas. Furthermore, the thrombolites in Oman are better preserved, both texturally and geochemically, allowing greater insight into the biological processes which influenced their growth.

Future Work. Future work will focus on the detailed description and comparison of internal microbial fabrics and associated skeletal fossils in both study areas. A quantitative determination of the volume of various microbial and shelly skeletal components, as well as the primary mineralogy of skeletons, other grains, and cements, will allow an estimation of how important different components have been in the construction of thrombolites. Once the relative roles of components in the construction of thrombolites are determined, more general conclusions regarding the ecological structure and succession of these buildups can be drawn.